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Public Health Service
Cincinnati, Ohio

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STUDY OF SLUDGE BULKING AT THE LANCASTER, PA. SEWAGE TREATMENT PLANT, NOVEMBER 20 - 26, 1935.

By

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December 20, 1935.

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Considerable trouble has been experienced with bulking of the sludge at the South Plant activated sludge sewage treatment works at Lancaster, Pa. Upon the request of City Engineer R. L. Kell, addressed to the Surgeon General, Special Expert W. C. Purdy and Associate Sanitary Engineer R. S. Smith were detailed to Lancaster to ascertain the direct cause and, if practicable, suggest some remedy for this difficulty. Messrs. Purdy and Smith were at Lancaster through the period of November 20-26, 1935, engaged in this activity.

The Lancaster Sewage Treatment Plants.

Lancaster, Pennsylvania has two practically new, activated sludge type sewage treatment plants, known as the North Plant and the South Plant. The two plants are identical in type, number and size of units, although, due to topographical conditions, the physical arrangement of the units is different. The plants comprise bar screens, grit chambers with mechanical scrapers, preliminary settling tanks with rectangular type mechanisms for sludge removal and skimming, three aeration tanks operating in parallel, two rectangular final clarifiers with scrapers for sludge removal and a sterilization building with chlorine equipment and dry feed machines for lime for sterilizing the final effluent during times of low flow in Conestoga Creek. Two heated digesters with gas holders and two sludge storage tanks are provided at each plant. The digested sludge is dried on underdrained sand beds. The main build-

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ing at each plant contains the office, chemical laboratory, shop, locker and toilet rooms, blowers, sludge pumps and heating plant.

There is a marked difference in the character of the sludge floc at the two plants and a great difference in the sewage tributary to the two plants.

The North Plant was put into service December 7, 1934, and no trouble from sludge bulking has been experienced. The sewage flow to the aeration tanks averaged 3.38 m.g.d. from November 14 to November 25, 1935, resulting in an average aeration period of 12.0 hours, with an average sludge return of 13.6 per cent of the sewage flow. The return sludge generally contains 2 per cent or more dry solids. The raw sewage entering the North Plant averaged 136 p.p.m. suspended solids and 128 p.p.m. 5-day B.O.D. for the period from November 1 to November 25, 1935. There is comparatively little trade waste tributary to this plant, the only industries being the Armstrong Linoleum Works and Cork Works. In the cork plant a chlorine bleach is used on the cork to destroy molds. It is not known whether or not small traces of chlorine from this source have any effect on the condition of the sludge floc.

The South Plant was put into operation May 20, 1935. The sewage flow is greater than at the North Plant and the sewage is stronger. The flow to the plant averaged 4.220 m.g.d. from November 1st to November 25th. If this had all been treated in the aeration tanks with a sludge return of 20 per cent of the sewage flow (the

average sludge return for this period) the aeration period would have averaged 8.3 hours. The raw sewage entering the South Plant during the same period averaged 205 p.p.m. suspended solids and 260 p.p.m. 5-day B.O.D. There are several industries tributary to this plant, some of them contributing very strong trade wastes. Among them are included gas works, a tannery, a slaughter house and a cotton mill. The cotton mill is devoted mainly to bleaching and dyeing fabrics, particularly such as awning materials, but two catch samples of the sewage show it to have an oxygen demand of 11,500 p.p.m. The sewage from the slaughter house is, of course, very strong, three catch samples showing an average oxygen demand of 16,000 p.p.m. Apparently due to the trade wastes, the strength of the sewage has a much greater variation during 24 hours on weekdays than it does on Sunday, the ratio of average to maximum B.O.D. being 1:2.05 on weekdays and 1:1.45 on Sunday (from two hour composite samples taken from September 18 to September 24, 1935).

Study of Sludge Bulking at the South Plant.

Operating features of the South Plant.

On arrival at the South Plant, arrangements were made for obtaining samples for microscopic examination. While these examinations were in progress, an inspection of the plant was made and operating conditions studied to determine the best place and method for the application of chlorine to the return sludge if that treatment were considered advisable.

The plant is equipped to chlorinate the effluent of the secondary sedimentation tanks. Two chlorinators of about 350 lbs. per day capacity each, with chlorine in one ton containers are installed in the "sterilization" building about 100 ft. from the outlet end of the secondary settling tanks. The return sludge is withdrawn from a sump at the inlet end of these tanks through 10 inch pipe lines connected to the suction of the sludge return pump located in the basement of the main building. The pump discharges the return sludge into the "control manhole" about 150 ft. away, where the sludge is mixed with the settled sewage flowing to the aeration tanks.

Three possible points for application of chlorine to the return sludge appeared feasible. One of these, the control manhole, would have necessitated moving the chlorinator, building a platform to set it on and enclosing it, as well as obtaining platform scales and a supply of chlorine in small cylinders. This work seemed very inadvisable if it could be avoided. It was found that by using a long hose for delivering the chlorine solution it would be possible to use the existing arrangement of the chlorinator in the sterilization building with a ton cylinder of chlorine on a dial type platform scale beside it. The chlorine could be introduced into the return sludge by tapping one of the 10 inch lines where they passed through a manhole on the way to the return sludge pump or by introducing the end of the hose into one of the 10 inch lines where it left the sump of the secondary settling tank. The latter method was considered the simplest for experimental

purposes if the hose end could be properly inserted in the pipe. One hundred and sixty feet of 3/4 inch garden hose was purchased and the connection between the chlorinator and the inlet end of the return sludge pipe was completed about 2:00 P.M. on Friday, November 22nd. A smaller chlorine orifice tube was installed in the chlorinator so that chlorine delivery could be reduced to about 20 lbs. per 24 hours.

During the course of this inspection, it was found that the aeration tanks had been emptied on November 18th in order to get rid of most of the poor sludge. The final settling tanks were not emptied in order to retain enough sludge to start the activated sludge units again. As a result, the suspended solids in the aeration mixture were 784 p.p.m. and about 4000 p.p.m. in the return sludge. By by-passing of some of the sewage around the activated sludge units, in an endeavor to control bulking, the flow had been reduced to 2.8 m.g.d., giving an aeration period of 13 hours.

The Biological Examination.

The troublesome, poorly-settling sludge of the South Plant was subjected to microscopic study in order to determine (1) the general character of the floc, and (2) whether attached fungus was present in sufficient quantity to constitute a factor in the poor settling.

By using a low-power binocular microscope magnifying about 20 or 30 diameters, adjusting the substage mirror at a point slightly in front of the optical axis of the microscope to secure a dark-

field effect, and using a dilution of the sludge in a cell about 1 millimeter deep (with cover-glass adjusted) the floating flocs could be seen clearly outlined against a dark field and any attached fungus was easily seen by reason of the light reflected from their minute filaments, affording a sharp contrast with the surrounding dark field. A true picture of the undistorted floating floc, as if it were in its natural environment in the clarification tank, was thus obtained. Such a true picture is very important, in order that sewage works men may see for themselves just what physical and biological conditions attend the floc, and the possible and probable connection between these attendant conditions, and the performance of the plant, particularly with respect to the proper settling of the sludge.

Examinations were made during the afternoon of November 20th and during November 21st, a total of 35 samples, all from the final clarifier tanks, being examined as a means of determining the outstanding characteristics of the floc and the probable reason for its poor settling.

All samples without exception showed:

(1) A medium sized, loosely-knit, spongy floc, with little or no definite center, and with ragged, sometimes stringy margins. In our judgment, the floc was of such a nature that it would not settle well, even if fungus were absent.

(2) Attached to much of the floc was a moderately heavy growth of fungus. This fungus was in excellent condition and its filaments extended out into the surrounding liquid for a

distance often equal to the diameter of the floc itself. In some cases portions of the floc margins were loosely built out along a part of the fungus filaments.

Former observation and study (chiefly at Cincinnati, Ohio) of some hundreds of sludge samples have indicated that:

(1) If floc has good, compact body, and is of normal size, such floc will settle well, even if attached fungus be present in moderate amount.

(2) If the floc body is poor and spongy, a small or moderate amount of attached fungus is sufficient to cause trouble in settling.

Diagnosis and the remedy suggested.

In the case of this plant at Lancaster, our diagnosis, based on extensive examinations of the floc, was that the trouble in settling was due to two factors, i.e. (1) the persistently poor floc body, and (2) the moderately heavy growth of attached fungus.

Former experience with fungus infested sludge had indicated that chlorine, applied in small amount, would tend to check and control fungus growth. We, therefore, suggested to the engineer in charge of the plant, the application of chlorine, believing that such treatment would lessen one of the troubles and improve the general situation by that much at least.

Application of chlorine was begun about 3:00 P.M. November 22nd, at the rate of about 4 p.p.m. or 0.1 per cent on a dry solids basis, and continued at the rate shown in the accompanying table:

Date	Time	Return Sludge Meter Integrator (Thous. Gals.)	Return Sludge Gals.	Chlorine Tank Weight Lbs.	Lbs. Chlorine Used	Chlorine p.p.m.	Return Sludge Susp. Solids p.p.m.	Chlorine % Dry Solids
11/22	3:00 PM.	195,700		3396				
11/23	9:00 AM.	196,223	523,000	3378	18	4.13	3800	.109
11/24	11:00 AM.	197,086	863,000	3343	35	4.86	4100	.119
11/25	10:45 AM.	197,876	790,000	3309	34	5.17	4000	.129
11/26	11:45 AM.	198,700	824,000	3280	29	4.23	2900*	.109
11/26	2:30 PM.	198,790	90,000	3278	2	2.67	4000	.067
Entire Period		3,090,000			118	4.57	Est. 4000	.115

*Evident error in composite sample. Estimated 4000 p.p.m.

Preparations were made to keep check, by frequent microscopic examinations, on effects produced by the chlorine (1) on the fungus, (2) on the other organisms, particularly the stalked ciliates. Epistylis was the genus most abundant, although Vorticella was present also. Research work had demonstrated that dosage of chlorine could be continued, without apparent harm to the activated sludge, until the stalked ciliates present began to show a decrease in their usual activity. Careful watch was, therefore, kept on the condition of these test organisms as the chlorine treatment progressed.

It so happened that the period of detention in the aeration tanks was about 13 hours, so approximately this period of time must elapse before samples taken in the final clarifiers would include the material to which chlorine had been applied. However, microscopic examinations were made frequently pending the arrival, at the sampling point, of the chlorine treated material, in order to secure adequate

data for comparison with such effects on fungus and on test organisms as might be produced by the chlorine.

Results of chlorine treatment.

About 25 hours after the beginning of chlorine dosage (or after actual contact with chlorine for about 12 hours) the fungus filaments began to show deterioration. This was observable (1) by a more or less wavy condition, as compared to the previous, normal relatively straight filaments, (2) by an abnormal "beaded" condition of an occasional filament. These waves of the fungus filament may become shortened until the word "curled" describes it more adequately. Under this chlorine treatment, it is believed that parts of the fungus filaments become detached. We have not observed the actual breaking, however. The statement just made is based on the following two observations:

(1) Chlorine treatment presently effects a shortening of the fungus filaments, and produces a somewhat tangled disorganized condition of such filaments as remain attached to the floc.

(2) During and after chlorine treatment the effluent showed increased turbidity. This was made up by minute fragments of floc, by colloidal matter, and by short lengths of free-floating fungus. So far as observed, the latter did not figure in the supernatant previous to treatment with chlorine.

At this same time (after contact with chlorine for 12 hours) the plankton organisms appeared to be quite unaffected. The dosage was at this time increased to about 5 p.p.m. Frequent examinations

followed, and showed a continued and increasing effect, as described above, on the fungus filaments. This continued until, after 18 hours' actual contact with a dosage of 5 p.p.m. of chlorine (which had been immediately preceded with 24 hours' contact with a dosage of 4 p.p.m.) it was quite evident that fungus growth had been checked. Chlorine dosage was, therefore, decreased to about 2 p.p.m. In another 36 hours (or a total of about 60 hours after actual presence and contact with the initial 4 p.p.m. dosage) it was noted that some of the stalked ciliates were becoming inactive, and the chlorine was stopped altogether, in order to avoid injury to the desirable organisms always present in activated sludge.

Apparently the chlorine treatment produced an additional effect on the body of the floc. This body had been noticeably spongy and loosely knit, and showed little if any tendency to form a definite center. This condition was apparently improved by the chlorine treatment in that the flocs showed better body, were less ragged, and a definite, brownish center was visible in an increasing number of the flocs. This improvement in the floc body was not expected, and we have no explanation to offer as to the mode of action involved.

There was another unexpected result of this chlorination of the return sludge. At the start of the experiment, the mixed liquor floc was very large and diffuse, the actual floc material seeming to be loosely bound together by fungus filaments. As the chlorine killed these binding filaments, the floc disintegrated somewhat, releasing many floc fragments, many of them so small that they

formed practically colloidal material. These fragments were extremely resistant to settling and made the effluent from the secondary settling tanks extremely turbid. Although the effluent had a very poor appearance, the suspended solids generally ranged from 20 to 30 p.p.m. and the per cent removal through the activated sludge plant varied from 68 to 74 per cent. It was thought that this effect would be only temporary and that after a time this fine material would be washed out and the effluent become more clear. There were definite signs by the late afternoon of November 26th that this was occurring.

Due to the possibility of over-chlorinating and destroying the normal plankton content of activated sludge, we would not recommend for ordinary use in plant control of fungus growths, such a heavy chlorine dosage as was used during this experiment. It is felt that normally a chlorine dosage of from .01 to .02 per cent of the dry solids in the return sludge would be sufficient to check the fungus growth, although a longer period would be required for its effect to be apparent. For this reason it was recommended that no more chlorine be applied for at least three days and that then, if chlorination were desirable, that chlorine be applied for four days at the rate of .01 to .02 per cent of the dry solids in the return sludge and chlorination stopped for three days, this cycle being repeated as necessary.

Observations Concerning the North Plant.

The North Plant, identical with the South Plant in design, capacity and operation, was giving practically no trouble, the sludge

was settling quickly and the supernatant was clear. Mr. Kell, the City Engineer, wished to know the type of floc prevalent and particularly if fungus, so abundant and troublesome in the South Plant, was present here also. Examining the sludge at Mr. Kell's request, it was found to be a typical nodular, compact, brown floc, with excellent opaque body and containing no fungus growth. So far as our observation goes, such floc always settles quickly.

The probable reason for the widely different types of floc in these two sewage plants may be traced, with reason, to the amount and kind of industrial wastes in the South sewage as compared with the industrial component of the North sewage. This conclusion results by a process of elimination, rather than by our available information as to the specific effects caused by such wastes as are present. This latter we do not know. We do know, however, that these two otherwise similar plants, (1) vary greatly in the amount and kind of industrial wastes received, and also that (2) they vary greatly in the prevalent type of sludge produced. In the last analysis there seems to be no adequate explanation of (2)(above) except the prevalent conditions expressed in (1).

It was mentioned by Mr. Goodell, Chemist in charge, that a minute quantity of chlorine remained in the chloride of lime bleach used by the Armstrong Cork Works when this waste was discharged into the sewage to be treated by the North Plant, and that the continuous presence of this light content of chlorine might successfully inhibit fungus growth.

The clarification tanks at the North Plant are in such con-

dition that a few fish (chiefly gold fish and catfish) have been living therein for some months and are apparently satisfied with their environment. In this connection, it is interesting to note that the sides of the tanks, also the shaft and scrapers of the sludge conveyor mechanism are thickly covered with a heavy "crop" of small finger-like tubes built by midge larvae (Chironomus) and that the small, blood-red larvae (so-called "blood worms") are consequently present in large numbers. This may account in some measure for the favorable environment for fish.

We were told by plant attendants that if the dissolved oxygen content in these tanks reached a low point of about 2 p.p.m., the fish responded to this condition by coming from the depths and "lipping" the water surface. On increasing the air in the aeration tanks, the dissolved oxygen content of the clarifier tanks was increased and the fish no longer lipped the surface.

Casting about for some remedy for the poor performance of the South Plant, some one had suggested seeding this plant with a quantity of good sludge from the North Plant. This had not yet been done when we arrived, but we advised against it, for the reason that the essential situation differed so much in the two plants (especially in the matter of industrial wastes, as already stated) that mere replacement of a small portion of the sludge with that of a different sort, a sort foreign to the prevalent environmental conditions of the South Plant, would in all probability be quite useless as a remedy.

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CONDENSED TABLE GIVING REPRESENTATIVE RESULTS FROM THE SIXTY-ODD SAMPLES EXAMINED AT THE SOUTH PLANT, LANCASTER, PA.

Date Nov.	Contact with Cl. Hrs.	Body of Floc	Margins	Attached Fungus	Plankton organisms Living Yes	Plankton organisms Living No	Remarks
20	0 (a) (Remarks)	Spongy, granular, loosely built.	Ragged. Built out somewhat on fungus threads	Mod. am't.	Yes. Chiefly stalked ciliates		(a) Before chlorine was applied.
21	0 (a)	Spongy & diffuse	Do.	Do.	Do.		
22	0 (a)	Do.	Do. Tendency to be stringy	Do. Long strands mod. common	Do.		Cl. applied at 3 PM. Will require 13 hrs. to arrive at sampling point.
23	5	Do.	Do.	Do.	Do.		No visible effects of Cl. on fungus after 5 hrs. (theoretical) contact of 4 p.p.m.
23	12	Do.	Do.	Do. An occasional filament is curled by the Cl.	Do.		After 12 hrs. contact with Cl., fungus is slightly affected.
24	30	Less spongy Many minute fragments making supernatant turbid	Still ragged	Mod. am't. (More filaments are curled)	Do.		After 30 hrs. contact, fungus shows more effects of Cl.

(Table Continued on Next Page)

Date	Contact with Cl.	Body of Floc	Margins	Attached Fungus	Plankton organisms Living		Remarks
Nov.	Hrs.				Yes	No	
24	42	Spongy, but a few flocs show improving centers. Many fragments present.	Somewhat ragged, but improved.	Filaments are shorter and many show curled condition.	Yes chiefly stalked ciliates		Effects of Cl. on fungus more pronounced.
25	57	Mod. diffuse, but 25% show improving central body.	Do.	Do.	Do.		Do.
26	76	Do. More than 25% show improving center.	Do.	Am't. reduced perceptibly	Some of the attached ciliates are inactive.		Am't. of Cl. reduced to avoid killing plankton organisms.
26	81	Slight but continued improvement. More than 33% show improving central portion.	Somewhat ragged, but not stringy	Fungus still present, but in small am't. Filaments are shorter.	Stalked ciliates living but are not normally active.		